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DR. A. H. R. GOLDIE, C.B.E., F.R.S.E.

Dr. A. H. R. Goldie retired on May 4, 1953, after nearly 40 years' service in the Meteorological Office. Dr. Goldie's early years were spent at Glenisla, Angus. He was a student at the University of St. Andrews and St. John's College, Cambridge, from which he graduated as a Wrangler in the Mathematical Tripos of 1913.

On joining the Meteorological Office in August 1913 he served successively in the Forecast Division, at Falmouth Observatory and as Senior Assistant at Eskdalemuir Observatory until June 1915. He was then commissioned in the newly-formed Meteorological Section, Royal Engineers and served overseas for the remainder of the First World War. He was Meteorological Officer to General Rawlinson at H.Q. Fourth Army for a considerable time. After setting up the meteorological organization for the British Forces in Italy late in 1917 and the first half of 1918, he returned to France and subsequently assumed command of the Meteorological Section with headquarters in Cologne. He attained the rank of Major and was twice mentioned in dispatches.

On demobilization in 1919 Dr. Goldie returned to the Meteorological Office as Superintendent of the Local Centres Division. He held this post until October 1924 when he was appointed Superintendent, Meteorological Office, Edinburgh.

During his period as Head of the Local Centres Division the results of his researches, then especially devoted to changes of upper air temperature in depressions and anticyclones, began to appear in papers in the *Quarterly Journal of the Royal Meteorological Society* and in letters to *Nature*. He was the first to notice, in 1923, the occurrence of multiple tropopauses. During the years at Edinburgh his abilities in research were revealed in an impressive series of papers in *Geophysical Memoirs*, the *Proceedings of the Royal Society of Edinburgh*, the *Transactions of the Royal Society of Edinburgh* and the *Quarterly Journal of the Royal Meteorological Society*. The subjects comprised the electrical systems in the high atmosphere producing magnetic storms, the physics of the development of the large-scale wind structure of depressions and the degree of its approximation to standard hydrodynamic vortices, diurnal variations in both frontal and air-mass rainfall, small-scale waves on surfaces of discontinuity and the associated pressure and wind variations, and the gustiness of wind in relation to type of air mass and wind speed. The approach to these diverse problems was characteristically realistic. In 1935 he revised and brought up-to-date Abercromby's

celebrated book "Weather". He proceeded to the degree of D.Sc. at St. Andrews in 1936 and has been a Fellow of the Royal Society of Edinburgh since 1925. His standing in terrestrial magnetism and atmospheric electricity was recognized internationally by his appointment in 1936 as Secretary of the International Association for these subjects; he held this post until 1947. Apart from his research activities Dr. Goldie carried a heavy load of official duties in Edinburgh, both in the climatological work, in which difficult legal questions often arose, and in the control of the three Scottish Observatories. He was also largely responsible for setting up the anemometer at Bell Rock lighthouse in 1929.

In 1938 when the Director began to plan a Research Organization in the Meteorological Office, one of his first steps was to transfer Dr. Goldie to Headquarters as Assistant Director with special responsibility for research. The outbreak of the Second World War interrupted the fulfilment of these plans, and in November 1939, Dr. Goldie moved to Stonehouse, Gloucestershire, as Assistant Director (Climatology and Instruments) in charge of the Marine, Climatological and Instruments Branches which had been evacuated from South Kensington. The research plans were only temporarily interrupted, and when the Meteorological Research Committee was set up in 1941 Dr. Goldie became responsible for the official administration of its work. He possesses to an exceptional degree a capacity for sound administration which he was able to exercise simultaneously with the carrying out personally of research of a high order.

On the reorganization of the Office early in 1948 Dr. Goldie became a Deputy Chief Scientific Officer and was appointed Deputy Director for Research. Since then he has been responsible for the general co-ordination of research and for more immediate direction of research into meteorological physics such as cloud structure, problems of turbulence and radiation, instruments, terrestrial magnetism and electricity, and has controlled the Observatories, the Meteorological Research Flight, and the Headquarters Branches concerned. Early in 1950 the Climatology Division and Marine Branch again came under his charge. Dr. Goldie has exercised a predominant influence in the development of the research facilities within the office. His encouragement and personal example will long be gratefully remembered by all those associated with him.

Early in the Second World War Dr. Goldie studied the physics of the formation of condensation trails by aircraft, then a serious military problem, and he produced a theory which permitted the height of trail formation to be forecast. The theory led to the printing of a new curve, the "Mintra line", on the Meteorological Office tephigram and to the formulation of rules for advising pilots on how to avoid trail formation. Dr. Goldie was also much concerned with research into atmospheric turbulence affecting aircraft, but his most recent personal researches have dealt mainly with the large-scale circulation of the upper atmosphere. He has, to mention only one aspect of this work, used the observations of humidity made in the stratosphere by the Meteorological Research Flight to deduce in broad outline the circulation of air from the high equatorial troposphere into the stratosphere over temperate latitudes.

In 1951, Dr. Goldie was appointed C.B.E. in recognition of his services.

Dr. Goldie first married, in 1928, Miss Marion Wilson of the staff of the Meteorological Office, Edinburgh. At Stonehouse Mrs. Goldie's personal work for the staff greatly mitigated the difficulties of evacuation and there was deep sorrow at the news of her death in 1948.

In 1952, to the pleasure of all their friends, Dr. Goldie married Miss Helen Carruthers of the scientific staff of the Climatology Division. Now with Dr. Goldie's retirement we have also to regret the resignation of Mrs. Goldie whose great ability in the application of statistics to meteorology has, in collaboration with Dr. C. E. P. Brooks, been shown in such important works as "Upper winds over the world" and the newly published "Handbook of statistical methods in meteorology".

We extend our best wishes to Dr. and Mrs. Goldie and look forward to many more contributions from them to meteorological knowledge.

The Director on behalf of the staff of the Office presented Dr. Goldie, at a small ceremony held in Victory House on May 1, with a cheque with which to buy a greenhouse. In making the presentation and expressing the good wishes of the staff, the Director referred particularly to the large number of subjects to which Dr. Goldie had contributed, from the structure of depressions to terrestrial magnetism, and to Dr. Goldie's ability to combine first-class research with administration. Dr. Goldie, thanking the staff, recounted some memories of life in the Office before 1914 and of those with whom he had worked in the Office.

Mr. R. G. Veryard, Assistant Director for Climatology, presented Mrs. Goldie on April 30 with a 20-in. slide-rule and a set of grape-fruit glasses from her friends at Harrow. Mr. Veryard referred to the work, in the application of statistical methods to meteorology, in which Mrs. Goldie had played an important part during her ten years' service and particularly to *Geophysical Memoirs* No. 85, "Upper winds over the world", and the newly published "Handbook of statistical methods in meteorology". Mrs. Goldie in reply spoke of the friendliness she had always found in the Meteorological Office and how she would always feel she belonged to the Office.

THE FORMATION OF NEW ANTICYCLONES

By R. C. SUTCLIFFE, Ph.D.

Summary.—Defining a new anticyclone simply as a new centre of high pressure on the surface synoptic chart, 42 cases over the Atlantic–west European region in 1950–51 were examined according to the associated 500-mb. patterns. Only 4 cases occurred with a simple sinusoidal oscillation in the upper westerlies north of a pre-existing subtropical anticyclone (classical general-circulation model), but 21 cases with such an oscillation when the surface pressure was already low to the south of the upper westerlies. Nine cases occurred with anticyclonic disruption of the upper westerlies and 8 were complex. The two processes, oscillation and disruption in the baroclinic zone, are common and regularly produce anticyclonic development, but the distinct new high centre is exceptional.

Introduction.—Depressions and anticyclones are for the most part the manifestation of eddies in an atmosphere which is perpetually turbulent on the

synoptic scale. The new depression or new anticyclone on the surface chart may then be expected to emerge from small beginnings, as it were from nowhere, in association with some self-developing distortion in the three-dimensional flow patterns, and such evolutions will naturally present deep-seated difficulties in practical prediction, difficulties which theoretical understanding will not necessarily overcome. At present the forecaster is assisted by a knowledge of the types of situation liable to give rise to new developments and by a knowledge of the typical patterns of behaviour; this investigation adds a little to this knowledge. Cases are examined where new anticyclones have appeared (on the surface synoptic charts) and are classified according to the associated behaviour patterns of the 500-mb. contours and the 1000–500-mb. thickness.

Data and classification.—The object is to obtain a representative sample of "new anticyclone formations" without making any assumptions as to their three-dimensional structure or to theory, to obtain the sample tolerably objectively and to exclude the weak, small-scale or ephemeral centres which have little dynamical significance. The area selected for study is shown in Fig. 1, and a "new anticyclone" is defined as a closed high-pressure centre on the synoptic charts published in the *Daily Weather Report* of the Meteorological Office (isobars at 4-mb. intervals); further, the centre must persist for at least 24 hr. and must not be continuous with a previous centre either inside or outside the area.

It will not be supposed that such a definition will catch all or even the majority of cases of essentially new "anticyclonic development", for typically, over the area concerned, the result of a new development is merely a ridge of high pressure or the movement of a pre-existing high, not a new centre. In this respect anticyclonic development differs from the cyclonic which normally gives rise to a new centre. This difference is partly a feature of the synoptic climate of the region and is not true everywhere.

Over the two years 1950–51, 42 cases were selected; they are listed in Table I.

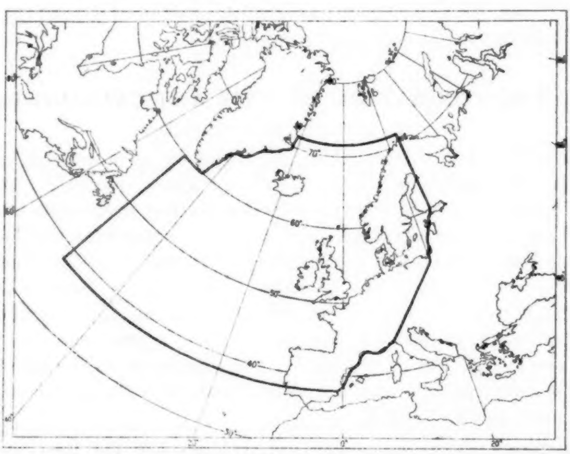


FIG. 1—AREA STUDIED FOR NEW ANTICYCLONIC CELLS

TABLE I—NEW ANTICYCLONIC CENTRES 1950–51

Total No. of Cases = 42

Type	Date	Location	Remarks
I—Simple upper oscillation in baroclinic zone with pre-existing anticyclone to south. No. of cases = 4	Oct. 20, 1950	East Atlantic	Illustrated in Fig. 2
	Nov. 4, 1950	North of British Isles	But initially lower pressure to south; almost type II
	Aug. 11, 1951	Central Atlantic	Tendency towards a double frontal system
	Oct. 26, 1951	Scandinavia	Soon absorbed high to south
II—Simple upper oscillation in baroclinic zone but without pre-existing high to south of anticyclogenetic region. No. of cases = 21	June 10, 1950	British Isles	Pre-existing cold depression Portugal, see Fig. 3
	July 2, 1950	British Isles	Low Spain to north Africa
	July 8, 1950	France	Low north-west Africa. Azores high
	July 12, 1950	France	
	July 18, 1950	France	
	July 25, 1950	France to Germany	Low north-west Africa. Weak oscillation
	Aug. 19, 1950	France to Germany	Low north-west Africa. Azores high. Weak oscillation
	Aug. 29, 1950	North Spain to France	
	Nov. 21, 1950	South of Greenland	Cut-off cold low to south
	Nov. 26, 1950	British Isles to Germany	Cut-off cold low Azores
	Dec. 1, 1950	South of Greenland	Cut-off cold low Azores. Large oscillation. See Fig. 4
	Feb. 28, 1951	France	Low Mediterranean. Large oscillation
	Apr. 16, 1951	East Atlantic	Cut-off cold low Azores
	Apr. 19, 1951	North Sea	Cut-off cold low Biscay
	May 29, 1951	North of British Isles	
	Aug. 17, 1951	South-west of British Isles	Low north-west Africa
	Sept. 14, 1951	North Spain to France	
	Sept. 16, 1951	South-east of Greenland	Cut-off cold low north-west of Azores
	Nov. 4, 1951	Scandinavia	Large cold low British Isles
	Nov. 15, 1951	North Scandinavia	Large cold low east Atlantic
	Dec. 12, 1951	East Atlantic	Low Azores
III—Anticyclonic disruption of upper wave pattern. No. of cases = 9	Mar. 8, 1950	East Atlantic	Cold low formed to west of Portugal
	Mar. 26, 1950	East Atlantic	Cold low moved to west of Portugal. See Fig. 6
	Apr. 20, 1950	Baltic	Cold low cut-off Mediterranean
	June 12, 1950	South-west of Iceland	Cold low cut-off north of Azores
	Aug. 30, 1950	Iceland	Cold low cut-off British Isles
	Feb. 12, 1951	North of British Isles	Cold low cut-off Biscay
	Mar. 23, 1951	Central Atlantic	Cold low cut-off south of Azores
	Apr. 25, 1951	Central Atlantic to south-west Iceland	Cold low cut-off Azores
	Apr. 9, 1951	France to Germany	Cold low cut-off Italy
IV—Complex No. of Cases = 8	Feb. 20, 1950	Central Atlantic	Double structure. See Fig. 7
	July 29, 1950	Jan Mayen	Low formed east of Greenland
	Nov. 4, 1950	North of British Isles	Double structure, lows to north and south
	Dec. 26, 1950	South Scandinavia	
	Mar. 20, 1951	British Isles	Almost type II
	June 6, 1951	Central Atlantic	Double structure, almost Type III
	July 11, 1951	South of Iceland	Small-scale feature
	Oct. 28, 1951	Central Atlantic	Small scale. Double structure

Each case, having been selected from the surface charts alone, was considered in the light of the upper air charts, mainly the 500-mb. contour charts and the 1000–500-mb. thickness charts. Leaving aside some 20 per cent. of cases which arose in complex synoptic situations, two distinct models became apparent: the sinusoidal oscillation of the upper westerlies and the disruption of the upper westerlies into two parts, both models being of course familiar enough to synoptic meteorologists. The types are discussed in separate paragraphs below and are illustrated with examples.

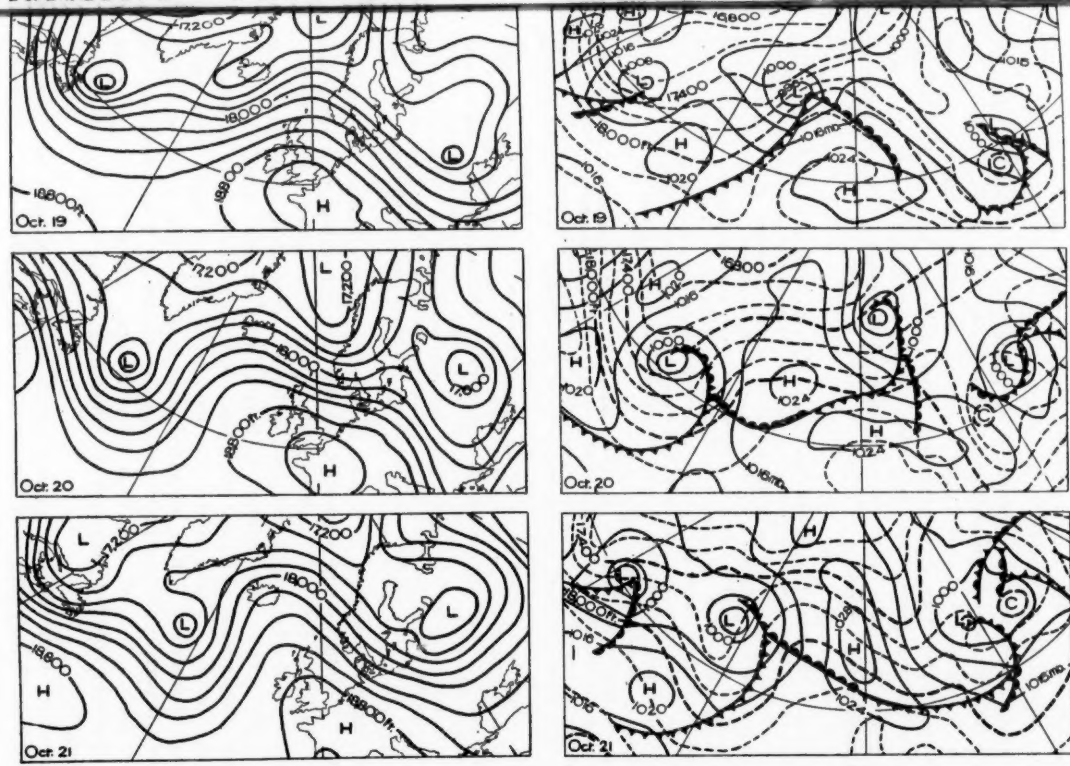
Simple sinusoidal oscillation.—The growing (unstable) wave model of the depression in a baroclinic zone is generally familiar, theoretically well founded and synoptically common. The corresponding anticyclone model is perhaps less well known, but the mechanism has been discussed briefly by Sutcliffe and Forsdyke[1]. There is still some doubt as to the exact criteria of "instability" if account is taken of all the controls, but certainly something of the kind is present somewhere at all times, and perhaps every steady baroclinic current is unstable for some such development of appropriate synoptic scale.

Classical general circulation model.—In the classical model of the general circulation of the atmosphere, with the unsettled westerlies lying on the poleward side of the subtropical anticyclonic belts, the typical sequence is one of developing, occluding and ultimately filling depressions separated not by closed anticyclones but by more or less intense wedges or ridges extending from the semi-permanent highs. Although this model is accepted and does not lack dynamical explanation the rarity with which a new high centre was in fact formed when the broad weather type in the region fitted this general circulation model, came as something of a surprise. The broad weather type is of course common over the Atlantic sector with the Azores anticyclone setting the pattern, and the degree of development of the baroclinic ridge is a regular and important problem for forecasting. But, excluding the cases where there was a temporary and weak closed centre, usually behind the cold front, but where otherwise the ridge construction was satisfactory, it was difficult to find a clear case of new anticyclone formation associated with the simple upper oscillation. Typically the ridge would relax within a day or two, and even in the cases where the development was strong and led to a large change in the broad weather pattern it was manifest by the old warm anticyclone being displaced to higher latitudes rather than by a definitely new surface formation. Fig. 2 illustrates a good example of pronounced anticyclonic building of this type. A few comments on the case follow.

October 19–21, 1950 (Fig. 2)

On the 19th there are two developing depressions in the Atlantic in the heart of the baroclinic zone shown by the thickness lines; the 500-mb. chart shows a rather weak sinusoidal pattern. The lower latitudes are dominated by the subtropical anticyclone lying south-west of the British Isles and outside the main upper stream of westerlies. The two depressions are separated by a baroclinic ridge from a detached high cell to the south. Over the next two days the depressions move east and the amplitude of the upper wave pattern grows considerably, the surface ridge develops at the same time, and by the 21st has effectively absorbed and displaced the old warm anticyclone into the baroclinic zone. There is, strictly speaking, no new anticyclone formation; rather the case illustrates the merging of two high centres into one. But there is very obviously a pronounced process of anticyclogenesis of the simple oscillation type.

In the two years only four cases of this type were picked out showing a distinct new surface centre, and none was very clear-cut or without some complicating factor. The conclusion is that anticyclogenesis associated with a simple oscillation in the upper westerlies north of a high-pressure belt may



500-mb. contour charts, 0300

Surface isobars, 0000, full lines
1000–500-mb. thickness, 0300, broken lines

FIG. 2—ANTICYCLONIC DEVELOPMENT WITH SIMPLE OSCILLATION IN THE UPPER WESTERLIES, OCTOBER 19–21, 1950

lead to a ridge (perhaps containing a weak separate cell) which is absorbed by the old subtropical high, or to one which itself absorbs the old high, but rarely to a distinct and detached new centre. Although the ridge model is well known to be typical, the rarity of the new detached high centre is rather remarkable when one recalls that a new cyclone centre regularly appears in the quite early stages of almost any cyclonic oscillation.

Non-classical broad-scale situation.—The position is very different when the broad weather situation is not roughly that of the classical general circulation model, when the region of upper baroclinic westerlies in which ridges and cyclones develop does not lie poleward of an established high but has generally low surface pressure at lower latitudes. This pattern can arise in many ways but there are certain rather common cases in our region. Two examples are illustrated in Figs. 3 and 4.

June 9–11, 1950 (Fig. 3)

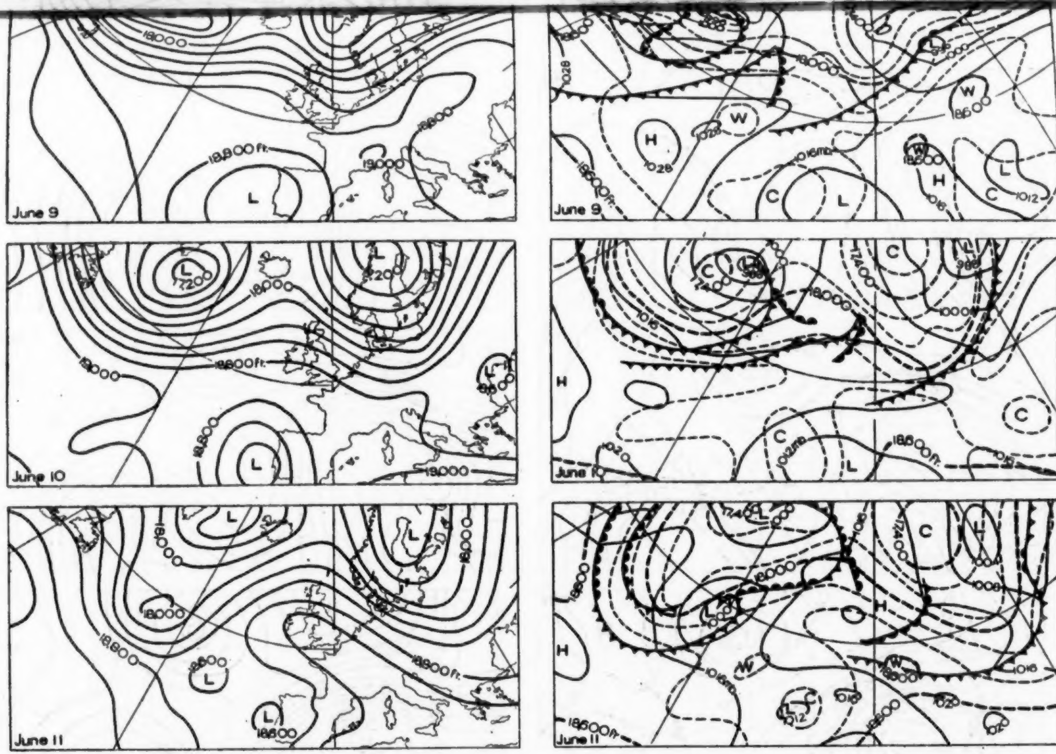
In this case the zone of upper westerlies shown on the 500-mb. charts is north of its mean position, and, as in the period October 19–21 there are two baroclinic depressions separated by a ridge extending, in this case, from the large high away to the south-west. There is, however, on the 9th generally low pressure over south-west Europe associated with a cut-off cold upper air vortex. As the sinusoidal wave pattern in the westerlies moves east and grows in amplitude the ridge breaks off from the high to the west thus giving a clear case of a new anticyclone. The example shows how a simple oscillation in the westerlies may readily give rise to a new high cell when there is no pre-existing anticyclone to the south of the anticyclogenetic region of the wave pattern, and a ridge construction is then hardly possible on geometry alone.

November 30–December 2, 1950 (Fig. 4)

There is clearly much similarity, in a broad sense, between this and the previous case. The main westerlies and the main baroclinic zone are again well north and there is already a large-amplitude oscillation. The low-latitude surface depression in mid Atlantic is completely cut off from the upper westerlies and is also thermally cut off as a cold pool. With further growth in the amplitude of the eastward-moving upper wave pattern a new high centre is formed on the 1st, this time appearing to detach itself from the high-latitude anticyclone. One can well imagine that if a similar oscillation were to arise in the absence of the low-latitude depression (that is if the Azores high were present as in the classical general circulation model) there might well be only a ridge development with no new high cell. Incidentally, the Atlantic situation on the 30th may be regarded as a "block" (higher-latitude high and lower-latitude low with separation of the upper westerlies into two branches), and a tendency for the block to be resolved can be seen on the 2nd by the cut-off, low-latitude, cyclonic vortex at 500 mb. being swept up, as it were, into the trough extension from the north-east.

The last two examples show clear cases when the new high, associated with a large oscillation of the westerlies, became a major feature near the British Isles, but, quite generally, whenever the upper westerlies run north of a low-pressure region high cells are readily formed even with quite small-scale oscillations. Thus it is common to have a more or less normal subtropical Atlantic anticyclone with a col extension across south-west Europe north of low pressure in the Mediterranean (common in winter) or over north Africa (typical of summer). Then, associated with ridges between travelling higher-latitude depressions, new high cells appear to detach themselves from the Azores high and move eastwards across Europe. These cells may be quite important for detailed, short-period forecasting. There were several cases in July 1950.

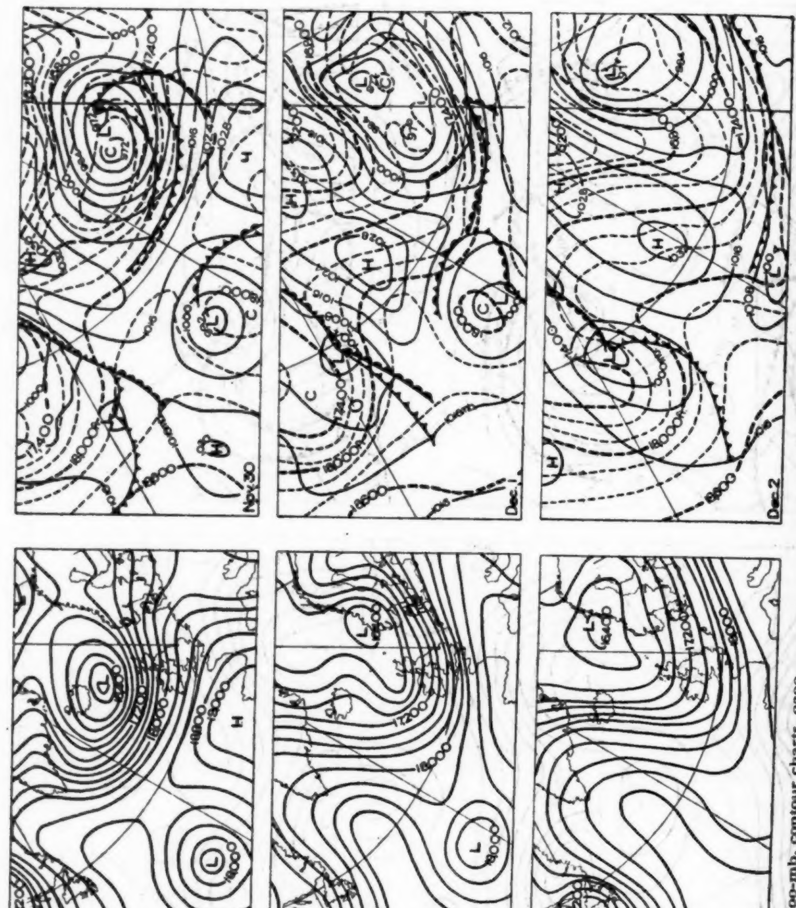
Something rather similar occurs when there is an occluded cold depression, say over the British Isles, with high-level westerlies continuing in a baroclinic zone at rather high latitudes (analysed as containing the arctic front). Then new high cells may appear to detach themselves from a semi-permanent high in the polar seas and move east or south-east into Scandinavia. These occur usually with quite conventional oscillations in the upper westerlies of these latitudes. There were two cases in November 1951.



500-mb. contour charts, 0300

Surface isobars, 0000, full lines
1000–500-mb. thickness, 0300, broken lines

FIG. 3—NEW ANTICYCLONE WITH OSCILLATION IN UPPER WESTERLIES NORTH OF PRE-EXISTING DEPRESSION, JUNE 9-11, 1950



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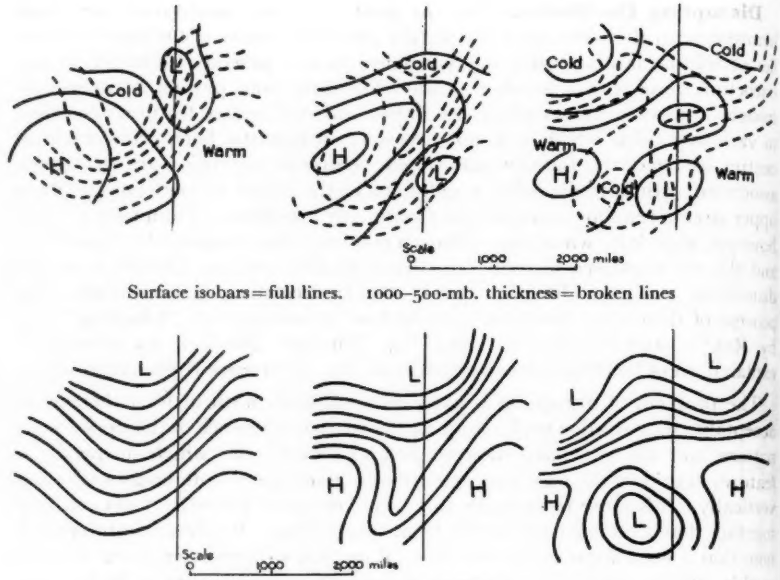
Surface isobars, 0000, full lines
1000–500-mb. thickness, 0300, broken lines

Disrupting Oscillation.—For the most part (but rarely over the whole hemisphere at the same time) the picture given by a study of the upper westerlies of middle latitudes and the associated surface pressure features is of one baroclinic zone with a number of wave-like distortions passing between cold troughs and warm ridges which are linked with the surface features according to various models which it is not necessary to describe here. New cyclonic centres are regularly, and new anticyclonic centres in our region are sometimes, associated with new sinusoidal oscillations in the upper current but the main upper stream remains concentrated around one maximum. From time to time, however, especially when the oscillation reaches a large amplitude, the current and the wave pattern disrupt, the stream divides and two distinct wave-like distortions move at different speeds rapidly becoming out-of-phase. This process of disruption has been described in connexion with "blocking" (e.g. by Rex[2,3]) and "cutting-off" (e.g. by Palmén[4]) although no satisfactory explanation of the dynamics or criterion for the occurrence is yet available.

The problem of disruption is likely to be difficult until at least there is an acceptable quantitative explanation of the spatial coherence of the upper wave pattern and the associated depressions and anticyclones which do persist as features in spite of the very large variations in wind speed both horizontally and vertically. It is more remarkable that any large-scale wave-like form can hold together than that it should disrupt from time to time. It is however relevant to note that a wave form in the westerlies, if moving with uniform speed over the earth's surface, will tilt forward at high latitudes merely owing to the shape of the earth while the Rossby retrogressive effect on the phase velocity $\beta L^2/4\pi^2$ (where β is proportional to the cosine of latitude and L is the wave-length) has a direct bearing on the relative stagnation of the lower-latitude wave form once disruption has occurred, and may be an important factor in the dynamics of disruption.

While, geometrically, the wave form is to be imagined as disrupting by relative progression either at the higher or the lower latitude the former would on the above considerations seem the more likely, and in fact does occur much more definitely and frequently. A schematic representation of the sequence of charts is shown in Fig. 5. It is characterized by the lagging behind of the low-latitude upper trough followed by complete disruption and the cutting off of a low-latitude upper low generally with a cold pool and also, in our region, a low-latitude surface depression; at the same time high pressure builds across the neck of the cut-off.

As the relative shear between the two parts of the trough is anticyclonic in sense, with the surface ridge across the neck appearing rather like a roller, the process will be called "anticyclonic disruption". Some nine of our new anticyclone centres appeared in this way, one of which is illustrated in Fig. 6 and discussed below. It must however be noted that the process does not normally produce a new high cell, according to our definition, but more commonly gives only a ridge development or a displacement across the neck of a pre-existing high from the west. Thus in the two years there were some 50 cases of anticyclonic disruption over the region; all gave a ridge building across the neck and all gave a cut-off low-latitude depression, but only nine clearly satisfied our criterion of formation of a new high centre; as in the case of simple oscillation the anticyclogenetic process is much more common than the emergence of a new, detached, high centre.



Surface isobars = full lines. 1000–500-mb. thickness = broken lines

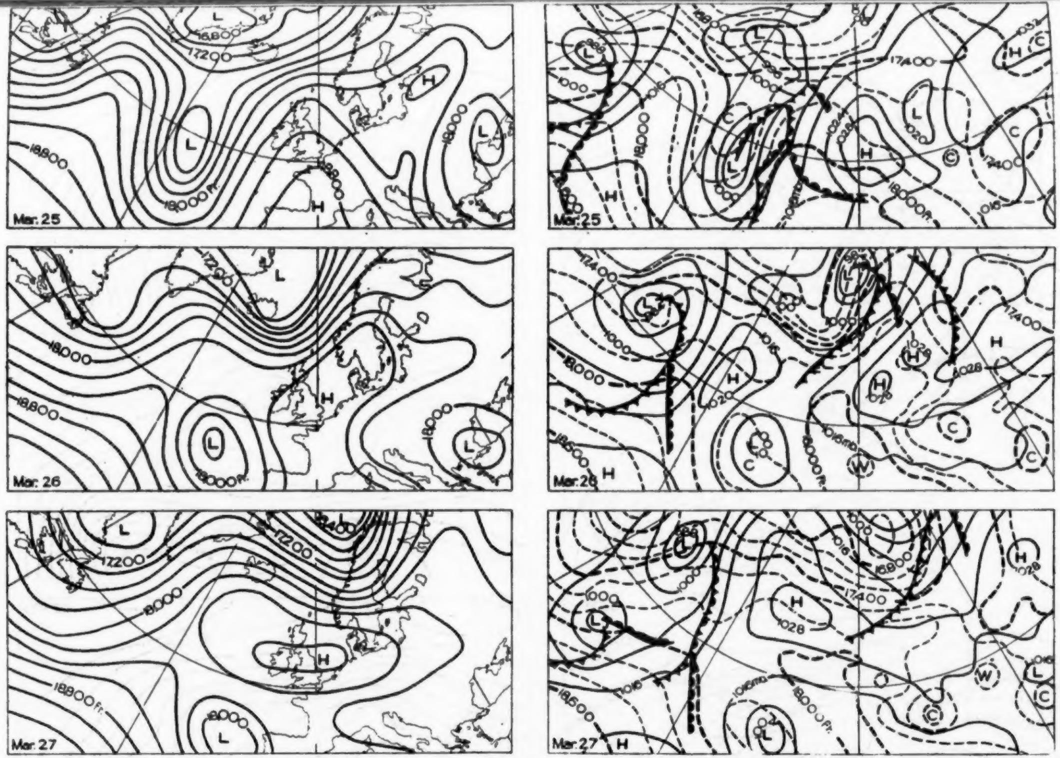
500-mb. contours = full lines

FIG. 5—SCHEMATIC MODEL OF ANTICYCLONIC WAVE DISRUPTION: PROGRESSION TO NORTH, STAGNATION AND CUTTING OFF TO SOUTH WITH SURFACE RIDGE BUILDING ACROSS THE NECK

March 25–27, 1950 (Fig. 6)

On the 25th the 500-mb. westerlies show one broad current across the Atlantic although the large-amplitude trough is already broken across the neck. At the surface there are two depressions associated with this upper trough, one to the east of the southern limit of the trough, the other further north. By the 26th the upper disruption is complete, the high-latitude part of the trough has moved to the north of Scotland lagging in phase behind the associated surface low in the normal way. The low-latitude part of the upper trough has moved more slowly and become a well separated vortex almost in phase with the cold pool and the surface depression. A new anticyclone now detaches itself from the ridge to the west and builds across the neck. By the 27th higher-latitude progression has continued, the new anticyclone is phased into the development region between the two depressions and is due north of the low-latitude cut-off low (so constituting a block in the westerlies).

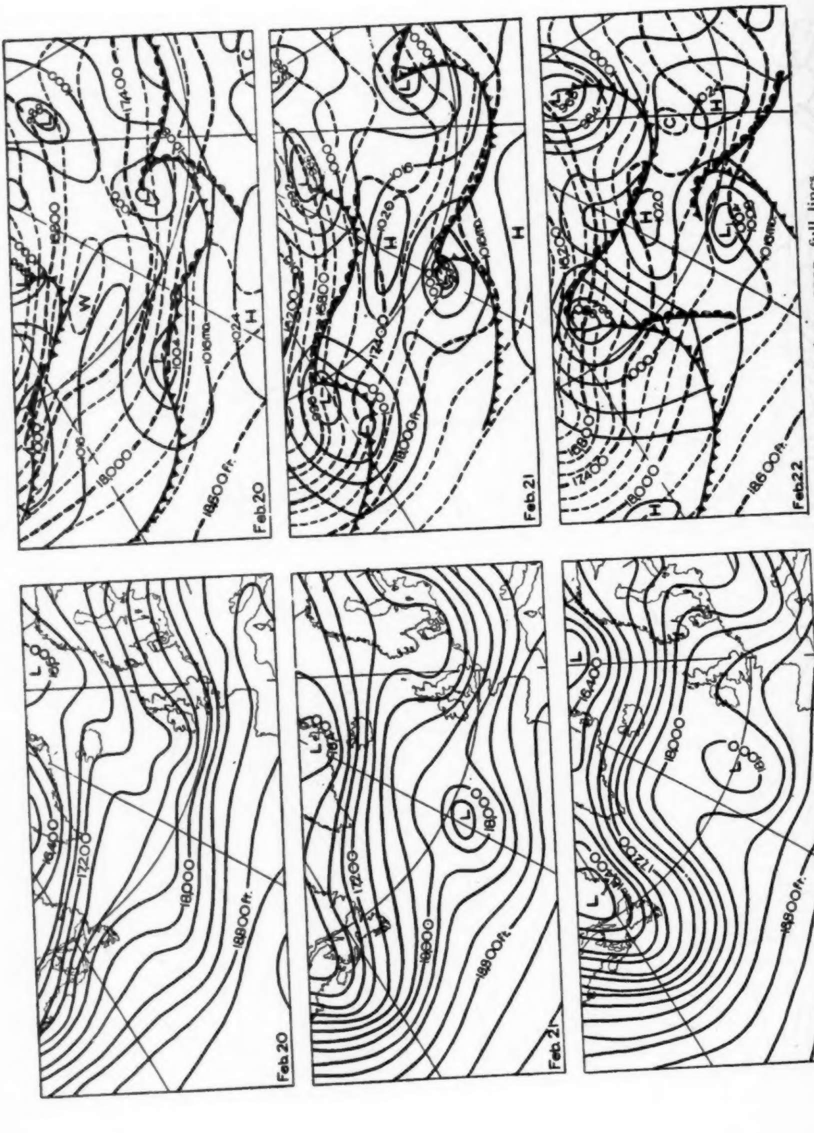
Although anticyclonic disruption is the common way in which a simple upper wave pattern may disrupt and the stream divide, an inspection of the upper charts alone will reveal cases where the southern part of an upper trough breaks forward and undercuts a higher-latitude ridge; a cold cut-off lower-latitude depression is the normal outcome. The process is found to westward of a blocked situation and is well illustrated by Berggren, Bolin and Rossby[5]. The immediate controlling system is a baroclinic cyclogenesis in the westerlies as they approach a strong diffluence and may be called a "cyclonic disruption". Although it is associated with a blocking high, even with its development or retrogression, there is no clear case of a new anticyclone appearing in the process over the two years considered, and, in spite of the importance of the situation in the general problem of anticyclones, it calls for no further attention here.



500-mb. contour charts, 0300

Surface isobars, 0000, full lines
1000–500-mb. thickness, 0300, broken lines

FIG. 6—ANTICYCLONIC DISRUPTION, MARCH 25–27, 1950



500-mb. contour charts, 0300

Surface isobars, 0000, full lines
1000–500-mb. thickness, 0300, broken lines

Complex situations.—Although it proved possible to classify some 80 per cent. of the cases into the two types of simple oscillation and wave disruption there remain a number of cases which can only be called complex, where more than one region of dynamical development, more than one system of depressions although to some extent independent, interact giving rise to a new high cell as an element in the complex. This sort of process is to be expected, and it is perhaps surprising only in that the number of cases is so small. The only approach likely to lead to useful comment is by quantitative dynamical analysis of each occurrence, and in the present state of quantitative methods one would not choose the unusually complicated as an exercise. One example is however illustrated.

February 20–22, 1950 (Fig. 7)

This is a clear case of two baroclinic zones over the Atlantic with two sets of frontal depressions. Between the two a new high cell is detached on the 21st in mid Atlantic and this later divides, one part phasing in between the pair of depressions in the north, the other dropping into place appropriately in the southern system over Europe. The northern high may be regarded as developing with the growing 500-mb. oscillation, as a simple case of the class studied on p. 168. But between the 20th and 21st there is deepening of four neighbouring baroclinic depressions simultaneously, a situation which is rare and may well be unprecedented in recorded meteorology.

Conclusions.—There are apparently only two modes of break-down of the zonal westerlies which give rise to new anticyclonic centres: the growing sinusoidal oscillation (unstable wave) and the anticyclonic disruption.

These modes of break-down are invariably associated with anticyclonic building at the surface but most commonly only a ridge or wedge development occurs. The new high centre is exceptional in the Atlantic–western European region, especially so when the broad synoptic situation is of the classical general circulation type (subtropical high pressure south of the baroclinic westerlies).

Although one or other form of dynamical break-down is essential for initiating an anticyclone it is evidently not sufficient to ensure the formation of a new centre or the development of an important system.

REFERENCES

1. SUTCLIFFE, R. C. and FORSDYKE, A. G.; The theory and rise of upper air thickness patterns in forecasting. *Quart. J.R. met. Soc., London*, **76**, 1950, p. 189.
2. REX, D. F.; Blocking action in the middle troposphere and its effect upon regional climate. *Tellus, Stockholm*, **2**, 1950, p. 196 and p. 275.
3. REX, D. F.; The effect of Atlantic blocking action upon European climate. *Tellus, Stockholm*, **3**, 1951, p. 100.
4. PALMÉN, E.; Origin and structure of high-level cyclones south of the maximum westerlies. *Tellus, Stockholm*, **1**, 1949, p. 22.
5. BERGGREN, R., BOLIN, B. and ROSSBY, C.-G.; An aerological study of zonal motion, its perturbations and break-down. *Tellus, Stockholm*, **1**, 1949, p. 14.

CLEAR-AIR TURBULENCE AT 20,000 ft. IN A FRONTAL ZONE

By I. J. W. POTHECARY, B.Sc.

At 1500 G.M.T. October 22, 1952, a Hastings aircraft of the Meteorological Research Flight was flying westward at 20,000 ft. over Southampton Water when turbulence was encountered for two minutes. The turbulence was classed as moderate to severe, and caused pronounced pitching and rolling which made positive control of the aircraft difficult. The true airspeed of the Hastings was 165 kt.; an aircraft flying at a much higher speed would probably have reported severe turbulence because of the greater accelerations.

The same course was maintained for a further three minutes in smooth air before turning on to a reciprocal heading. Three minutes later turbulence was

again encountered for about the same period as before. Unfortunately a fuller investigation of this turbulent region could not be made as the aircraft developed engine trouble and had to return to base.

The normal character of the turbulence met with near the surface, or in stratocumulus and in some layers of medium cloud, is similar to the bumpiness felt in driving over a cobbled road. On this occasion a longer-period component of the turbulence gave the impression that there were irregular dips and humps in the road.

Upper air information.—The cross-section in Fig. 1 shows the position of the front and the jet stream between Camborne and Hemsby. The frontal zone was associated with an active warm front reaching the surface about 300 miles to the south-west of Scilly.

A comparison of the temperatures taken from the aircraft on the ascent with those of the simultaneous radio-sonde ascent from Larkhill shows similar features, see Fig. 2. The apparent overall increase of the temperature as measured from the aircraft is probably due to instrumental lag as measurements

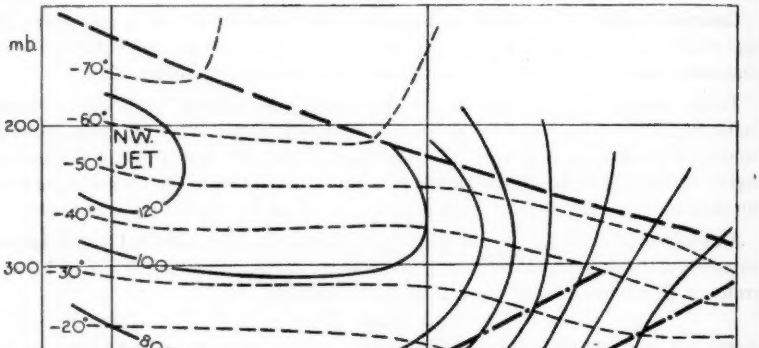


FIG. 1—CROSS-SECTION FROM NORTH-EAST TO SOUTH-WEST, 1500 G.M.T., OCTOBER 22, 1952

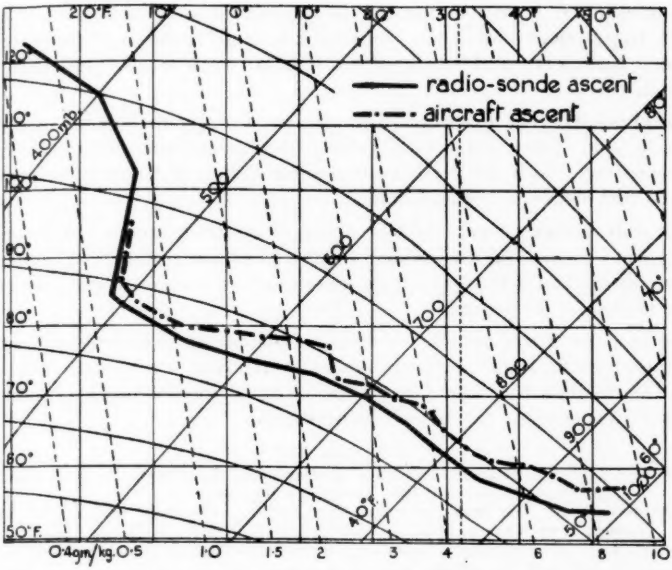


FIG. 2—COMPARISON OF AIRCRAFT TEMPERATURE ASCENT WITH RADIO-SONDE ASCENT FROM LARKHILL, 1500 G.M.T., OCTOBER 22, 1952

were made while the aircraft was climbing rapidly. The similarity of the ascents is thought to justify the use of the cross-section as a description of the conditions over Southampton Water which is about 30 miles south-east of the plane of the cross-section. Differences due to the distance are minimized by the fact that the jet stream is north-westerly and the front lies in the same direction.

An important feature of the temperature curve is the inversion of 3°F. through the frontal zone between 18,500 and 21,000 ft. The turbulence occurred within this region. The component part of the wind shown in Fig. 1 is the major part of the resultant wind in the turbulent region (T) so that a representative value of the wind shear can be obtained directly from the information given.

Vertical shear.—The vertical shear through the turbulent region is large, averaging 10 kt./1,000 ft. over 5,000 ft. It is probably stronger over a smaller height interval. Because of this large shear it is likely that the turbulence on this occasion was primarily due to vertical shear although horizontal shear was sufficiently large to indicate the possibility of turbulence from this cause alone.

Horizontal shear.—The horizontal shear along the north-east to south-west line of maximum shear through the turbulent region is 0·40/hr. In a previous analysis[1] of a report of severe clear-air turbulence at 30,000 ft. the associated horizontal shear was of the same order as in the present case.

Richardson's number and vertical shear.—L. F. Richardson[2] related static stability and wind shear to give a dimensionless number (R_i) which is related to the nature of flow in the atmosphere. As a criterion for the increase or decrease of turbulence Richardson used R_i less than or greater than unity. On this occasion, considering the vertical shear alone, the value of R_i was 1·59.

Bannon[3] used R_i as a parameter in an investigation of turbulence in the upper troposphere and lower stratosphere, and found a definite relation between turbulence and small values of R_i at these levels (i.e. values of R_i less than 10).

Conclusion.—The existence of moderate to severe turbulence in a region of strong wind shears, with a small value of the Richardson number ($R_i = 1 \cdot 59$), is in agreement with the evidence that small values of R_i are associated with marked turbulence in the atmosphere.

The only known criteria for forecasting clear-air turbulence at present are strong wind shears and low values of the Richardson number. These criteria are usually applied to the upper troposphere and lower stratosphere, particularly in the vicinity of jet streams.

The analysis of this occasion of clear-air turbulence is interesting, in that it shows that if the requisite conditions exist at lower levels such as in a dry frontal zone, then the same criteria are of equal importance in assessing the likelihood of clear-air turbulence being found.

REFERENCES

1. BANNON, J. K.; Severe clear-air turbulence experienced at high altitude on the 2nd and 7th of November 1950. *Met. Res. Pap., London*, No. 631, 1951.
2. RICHARDSON, L. F.; The supply of energy from and to atmospheric eddies. *Proc. roy. Soc., London*, A, **97**, 1920, p. 354.
3. BANNON, J. K.; Meteorological aspects of turbulence affecting aircraft at high altitude. *Prof. Notes met. Off., London*, **7**, No. 104, 1951.

JET STREAM OF OCTOBER 28, 1952

By D. H. JOHNSON, M.Sc.

The jet stream which affected the British Isles on October 28, 1952, attracted an unusual degree of interest at the Central Forecasting Office, Dunstable. Very strong winds were reported at comparatively low levels within the current, and one ascent made at 0900 G.M.T. into the core of the jet stream showed the strongest wind to be located near the 500-mb. level. Since, in the autumn season near the British Isles, jet-stream centres normally occur between 300 mb. and 200 mb., it was thought that the phenomenon merited brief investigation, a short account of which is given below.

Synoptic situation.—At 0300 G.M.T. a jet stream flowed from the south-west towards the British Isles (Fig. 1). At the surface, a very deep depression was centred to the north-west of Ireland and was moving steadily north-east as an associated frontal system crossed the country. Fig. 2 contains a vertical cross-section, taken through the exit of the jet stream, normal to the direction of flow at the jet centre, the isokinetics giving the component of wind speed perpendicular to the line of section. Beneath the jet stream there was unusually strong flow down to the 900-mb. level and the greatest baroclinity occurred below 550 mb.; only weak thermal gradients existed between 550 mb. and the top of the troposphere. The exact level at which the wind maximum occurred is a little in doubt; as drawn its position agrees with the Aldergrove upper winds but the decrease of wind above 400 mb. depends on an observation made when reception of the reflected radar signals was poor. From the temperature field alone, one might expect to find the highest wind between 350 and 300 mb. The section lies almost parallel to an occluded surface front which was not clearly marked in the thermal field. The warm-air tropopause was ill

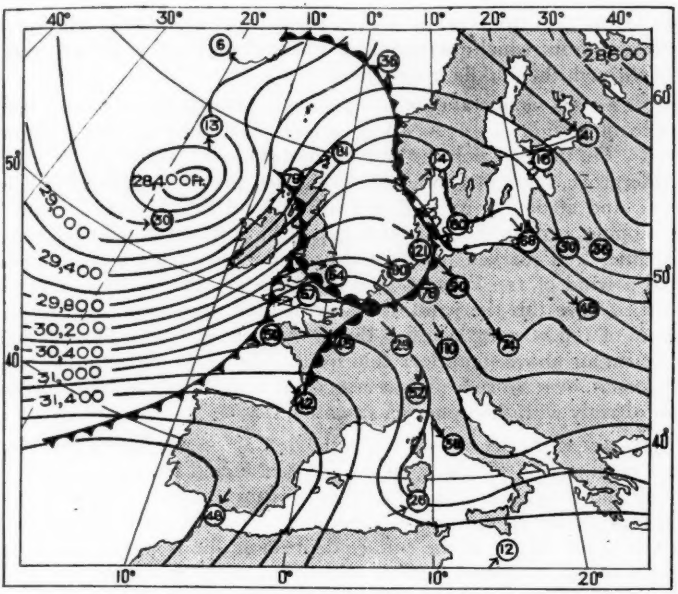


FIG. 1—300-MB. CONTOUR CHART, 0300 G.M.T., OCTOBER 28, 1952
Erratum: *for* "30,400 ft." *read* "30,600 ft."

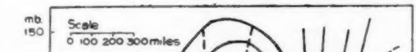


FIG. 2—CROSS-SECTION THROUGH LIVERPOOL NORMAL TO THE UPPER FLOW, 0300 G.M.T., OCTOBER 28, 1952

- - - - - Isotherms

——— Isokinetics, positive for WSW. wind components

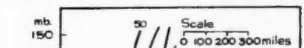


FIG. 3—CROSS-SECTION THROUGH LIVERPOOL NORMAL TO THE UPPER FLOW, 0900 G.M.T., OCTOBER 28, 1952

——— Isokinetics, positive for WSW. wind components

defined. Upstream from its exit the jet stream was more definitely associated with the cold front which the ascent at Valentia shows to have been very well marked through the middle troposphere.

Fig. 3 is a cross-section at 0900 G.M.T. drawn through the jet stream along the same line of section (at 0900 G.M.T. upper winds but not temperature are observed). On this occasion the ascents from station I (59°N., 19°W.), Stornoway, Aldergrove, Liverpool and Larkhill reached 30,000 ft., 53,000 ft., 48,000 ft., 39,000 ft. and 28,000 ft. respectively, so the wind field is well defined. The strong, sloping, cyclonic shear zone suggests that the associated cold front was, at this time, well marked in the middle and upper troposphere. Liverpool reported a wind of 110 kt. at 14,000 ft. and a maximum wind of 147 kt. at 19,000 ft. Above this the wind decreased a little, but there was a secondary maximum of 129 kt. at 27,000 ft. Evidently there was little thermal gradient in the warm air above the upper cold front. The wind maximum of 80 kt. at about 5,000 ft. over Stornoway was associated with the deep surface depression and not directly with the upper jet stream.

By 1500 G.M.T. the jet stream had extended across the North Sea (Fig. 4), and the cross-section of Fig. 5 again shows the cold front to be very strong thermally and to contain most of the temperature contrast between the warm and cold air masses in the upper troposphere. To the north of the cold front and south of the centre of the surface depression, the troposphere was largely barotropic so that the wind field showed little change from the surface almost to the top of the troposphere. However, to the north of the centre of the depression the atmosphere was sufficiently baroclinic for the easterly flow to become negligible at the 300-mb. level.

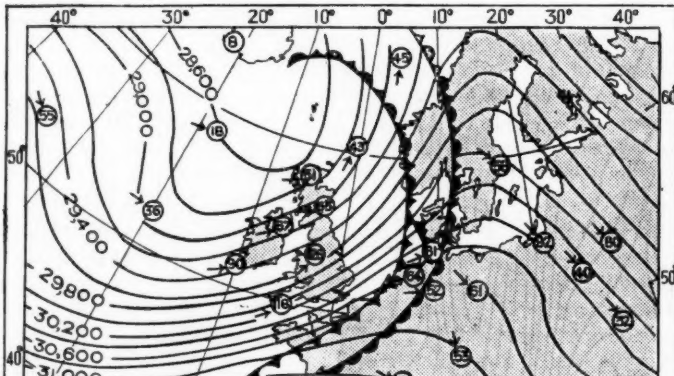


FIG. 4—300-MB. CONTOUR CHART, 1500 G.M.T., OCTOBER 28, 1952

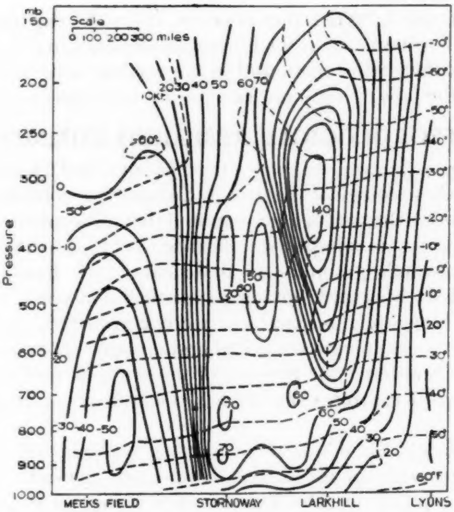


FIG. 5—CROSS-SECTION THROUGH LIVERPOOL NORMAL TO THE UPPER FLOW, 1500 G.M.T., OCTOBER 28, 1952

- - - - - - Isotherms
——— Isokinetics, positive for WSW. wind components

Comment.—The feature which led to the construction of these sections was the occurrence of the wind maximum at 0900 G.M.T. above Liverpool at 19,000 ft., apparently well beneath the region of the tropopause. It is clear that away from the delta region, where there are always complexities, the jet stream was characterized by the unusually intense sloping frontal zone and the quasi-baroclinic nature of the warm air above the front. These features appear to have been particularly well developed at 0900 G.M.T. when the vertical wind profile through the core of the current had an exceptionally flat maximum with minor peaks at 19,000 ft. and 27,000 ft. In view of this the occurrence of the highest wind speed at 19,000 ft. is a little less surprising since an additional, possibly ageostrophic, wind component at that level of only some 20 kt. has to be accounted for. Examination of the graph of rate of ascent plotted against time for the ascent at Liverpool at 0900 G.M.T. indicates that the 147-kt. wind occurred over a minute interval when the apparent rate of ascent of the balloon was about 500 ft./min. greater than average. A possible explanation of the phenomenon, which could account for additional components of both vertical and horizontal speed of the required order of magnitude, is that the effect was due to a standing wave set up in the solid south-westerly flow over the Welsh Mountains. However, since the exceptional horizontal and vertical displacements of the balloon took place over the same minute interval the possibility of an error having been made in the measurement of the slant range of the balloon cannot be discounted.

Summarizing briefly: at one stage in the history of this jet stream its thermal structure appears to have approximated to the simple model of a sloping frontal layer separating two barotropic air masses. Experience shows such a

structure to be unusual. When it does occur, it is to be expected that the exact position of the jet-stream axis in the horizontal depends to a greater extent than is usual on the surface wind field, and in the vertical depends largely on minor irregularities of the flow; it may not be situated very close to the tropopause.

METEOROLOGICAL RESEARCH COMMITTEE

At their meeting on January 29, 1953, the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee considered a paper by Mr. Sawyer[1] in which the author demonstrated that atmospheric inhomogeneities in temperature having no synoptic significance may lead to "kinks" on an upper air temperature sounding similar to those caused by frontal surfaces. Two papers by Mr. R. F. M. Hay[2,3] giving a statistical analysis of upper winds over Singapore and Hongkong respectively were considered, and Mr. Sumner[4] presented a paper containing a statistical and synoptic study of cold pools. The Committee also considered the revision of the synoptic and dynamical part of the Meteorological Research Committee's research programme.

At the Instruments Sub-Committee meeting on February 5 the Committee considered the accuracy of the British radio-sonde 300-mb. contour observations, and also a paper by Dr. Palmer[5] describing an improved automatic frost-point hygrometer, an instrument which promises to be of great value. Recommendations for revision of the instruments part of the Meteorological Research Committee's research programme were also agreed.

At the Physical Sub-Committee meetings on February 10 and 23, the technical reports considered included a paper by Mr. R. Frost[6] summarizing the meteorological aspects of the "Singapore cloud detection trials" in which an aircraft fitted with radar investigated the characteristics of clouds from which a radar echo was obtained. Dr. Scrase[7] presented a paper in which he had used the detailed measurements made on an upper air sounding to obtain a picture of the turbulence in the upper air. The variation of wind in short periods of time between 30,000 and 35,000 ft. was also discussed in a paper presented by Mr. Durst[8]. Dr. Goldie[9] gave an account of the global circulation of stratosphere air and the mechanism of change of tropopause level.

The Sub-Committee also considered the revision of Part III of the research programme and the Annual Report.

The main Committee met on March 20. At this meeting the Annual Reports from the Sub-Committees were received and the revision of the research programme for the coming year approved. The Chairman's Annual Report to the Secretary of State for Air was also agreed.

ABSTRACTS

1. SAWYER, J. S.; The effect of atmospheric inhomogeneity on the interpretation of vertical temperature soundings. *Met. Res. Pap., London*, No. 775, S.C. II/132, 1952.

Small-scale temperature fluctuations (radius 50 Km. or so) limit interpretation of vertical soundings. Flight grids in a homogeneous air mass gave standard deviation of about 0·5°F. in normal layers and 0·75°F. in stable layers. Vertical correlation between fluctuations varies from 0·85 for small separation to zero for 2,000 ft. From these facts it is found that any departure of less than 1·5°F. from a smooth curve must be treated with caution.

2. HAY, R. F. M.; Wind at high levels over Singapore (1950–52). *Met. Res. Pap., London*, No. 770, S.C. II/130, 1952.

Summary of 149 radar observations, of which 101 exceeded 55,000 ft. and 18, 70,000 ft. Easterlies are found above 25,000 ft., very strong (some over 90 kt.) in 48,000–54,000 ft. There is

a strong shear at about 60,000 ft. to SW., sometimes exceeding 10 kt./1,000 ft. Tables show vector resultants at each month and height, scalar speeds, highest speeds and corresponding heights, shear values and frequencies integrated through layers.

3. HAY, R. F. M.; Wind at high levels over Hongkong. *Met. Res. Pap., London*, No. 778, S.C. II/135, 1952.

Radar and radio-sonde winds 1950–51 are tabulated and graphed for 850–60 mb. Daily observations show almost abrupt change from mostly westerlies to easterlies at 100 mb. in late May and back in early or mid October; at 150 and 200 mb. duration of easterlies is shorter. Extremes were 123 kt. from 268° and 78 kt. from 40°.

4. SUMNER, E. J.; Cold pools: a statistical and synoptic study. *Met. Res. Pap., London*, No. 764, S.C. II/125, 1952.

Thickness (1000–500 mb.), intensity and movement of cold-pool centres in 60°W.–30°E. south of 80°N. are plotted and tabulated; mainly late spring and early summer. Mean duration 3 days. Origin (mostly by cutting off a cold trough) examined. Associated pressure systems are classified into 6 types and distribution discussed. Tables and graphs show surface pressure at centres of pool and of associated high or low, cloud frequencies, type of precipitation and central thickness. Forecasting applications are considered.

5. PALMER, H. P.; An improved automatic frost-point hygrometer. *Met. Res. Pap., London*, No. 774, S.C. I/72, 1952.

An improved and simplified ex-Elliott automatic hygrometer with a germanium thimble, for use in aircraft, is described with diagrams of construction.

6. FROST, R.; Meteorological report on the Singapore cloud-detection trials. *Met. Res. Pap., London*, No. 757, S.C. III/141, 1952.

Runs were made towards and through cumulus and cumulonimbus by aircraft with 3-cm. radar. Heights of cumulus giving radar echo 13,000–33,000 ft., many below freezing level; cumulonimbus 29,000–55,000 ft. At transition level temperature is $-30°$ to $-35°$C. Mean diameter, visual, 6 miles; radar $4\frac{1}{2}$ miles. Occasions of hail and of snow tabulated; risk of severe icing small. Lightning occurred only with cloud top above 35,000 ft. up- and down-draughts tabulated; maximum up-draughts 53 ft./sec. Gust accelerations summarized in relation to position in cloud. Practically all turbulence can be avoided by avoiding radar-response areas by a mile.

7. SCRASE, F. J.; Turbulence in the upper air, as shown by radar wind and radio-sonde measurements. *Met. Res. Pap., London*, No. 771, S.C. III/144, 1952.

After allowing for random errors, eddy velocities were obtained from minute by minute radar winds on a radio-sonde up to 30 Km. over Downham Market. Mean wind 25 kt., fluctuations 5–10 kt. in periods of 3–4 min. Temperature fluctuations were 0·85°F. in troposphere and 0·64°F. in lower stratosphere. Results are used to estimate momentum and heat fluxes and coefficients of eddy diffusion and their bearing on the theory of heat diffusion is discussed.

8. DURST, C. S.; The variation of wind in short periods of time between 30,000 and 35,000 ft., January 1950 to January 1952. *Met. Res. Pap., London*, No. 745, S.C. III/140, 1952.

Observations of 86 pairs of smoke puffs emitted by aircraft at Orfordness, England, at intervals of 10 min. are used to calculate vector change of wind (kt./10 min.). Values ranged from 0·7 to 21·0; the larger ones tended to occur with greatest wind speeds and near tropopause or in stratosphere.

9. GOLDIE, A. H. R.; The global circulation of stratosphere air and the mechanism of change of tropopause level. *Met. Res. Pap., London*, No. 734, S.C. III/134, 1952.

January and July temperature and potential temperature, 500–90 mb. at Larkhill are plotted in relation to tropopause pressure and to tropopause at equator. The marked discontinuity at tropopause is attributed to slow air flow towards equator below and from equator above it. Steepness of the fall of potential temperature in latter current while descending 11,000 ft. points to a continual loss of heat, 67 per cent. of adiabatic gain in January and 52 per cent. in July being lost by radiation. This requires 3–4 weeks. Polar minima require loss of all or more of adiabatic gain. More rapid displacements of tropopause require convergence and vertical motion; the mechanism is discussed with examples.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held on January 21, 1953, a discussion was held with the British Gliding Association on the subject of "Fair-weather cumulus".

Dr. A. A. Yates described his experiences of convection elements. He said that "bubbles" of warm air broke away from the heated ground at an average rate of one in ten minutes though there was much variation, and that an average "bubble" had a diameter of some 1,000 ft., was about 1°C. warmer than the surrounding air, and rose at about 15 ft./sec. He gave a rough theory of the rate of rise of a "bubble", considered as a sphere of buoyancy balancing drag,

which tended to show that the rate of rise was proportional to the square root of the excess temperature inside the "bubble". He thought "bubbles" had a wake in which the warm inner air mixed with the surrounding air so that the shape became more and more elongated as the "bubble" rose. He stressed the need for more detailed observations, especially of temperature excess.

Dr. D. G. James of the Meteorological Research Flight described observations made with highly sensitive thermometers and hot-wire anemometers during a flight in a Hastings aircraft below fair-weather cumulus with base 3,200 ft. over Hampshire on August 28, 1952. The observations showed that below 1,000 ft. there were many convection "bubbles" having diameters of 200–4,000 ft. with a temperature excess in the interior of about 1·0°F. Above 1,000 ft. and below 3,000 ft. the records showed a marked decrease in the number of "bubbles". At these levels their diameters were almost entirely within the 200–1,000-ft. range (although one "bubble" appeared to have a diameter of 8,000 ft.) and they had a temperature excess of 0·3°–0·4°F. Above 3,000 ft. and below cloud base there existed a third region, the sub-cloud layer, which showed slow large temperature variations over distances of about 2 miles in addition to a sharp rise of temperature produced by a "bubble" of about 1,000-ft. diameter. The slower change was attributed to the descent of air from the sides of the developing cloud, whilst the increased bumpiness there was tentatively associated with the mixing of air of several different origins at this level.

Mr. Welch said "bubbles" stayed at much the same size as they rose, and described the diurnal variation of the strength and rate of formation of "bubbles". In the morning they were small but strong, and in the evening as strong as in the afternoon but formed less frequently. Fair-weather clouds were hollow at the base with an indentation which might be 250 ft. deep in a large cumulus. He added that marked contrasts of temperature, such as were found near large rivers, stimulated "bubble" formation.

Mr. F. H. Ludlam described temperatures measured with an Imperial College glider which showed an almost isothermal layer of air just below the base of cumulus clouds. He showed cine-films of air bubbles rising through water and speeded-up films of cumulus development.

Mr. F. G. Irving described temperature observations made at Cranfield which showed much smaller temperature excess than the values given by Dr. Yates.

Mr. Poulter suggested the low lapse-rate zone just below the cumulus clouds was above the condensation level and was the zone in which the droplets grew to visible size.

Professor P. A. Sheppard referred to the need for theoretical meteorologists to tackle the convection problem.

Dr. R. S. Scorer, in summing up the discussion, supported Dr. Yates's demand for glider pilots to make more scientific observations, and congratulated the Meteorological Research Flight on its successful observations of convective movements.

ROYAL ORNITHOLOGICAL CLUB

Bird migration through Great Britain in different synoptic situations

On December 17, 1952, a meeting of the Royal Ornithological Club was held at which K. Williamson read a paper on "The nature of spring and autumn

passage migration through Britain". Mr. Williamson based his paper on observation of bird movements at Fair Isle throughtout 1951, a year which he said proved suitable for this purpose as the quality of spring and autumn migration was excellent. Migration at Fair Isle was found to be most marked in both spring and autumn with E. and SE. winds; this was true for both north and south bound birds. There was often a pronounced double peak in the passage of a given species at either season, the first peak coming with easterly weather, the second following a few days later in quiet anticyclonic weather. A significant fact which led to the theory put forward later in the paper was that migrant birds reaching Fair Isle were found to have lost 20–30 per cent. of their normal body weight during their overseas flight. Since birds cannot lose weight at this rate for very long before exhaustion and death follow, it is concluded that birds do not undertake such long sea crossings if an alternative overland or coastal route exists.

Previous to this work other meteorological factors, variations in temperature and pressure, passage of warm and cold fronts were considered to be the main factors influencing migration. In 1951 the migration data obtained at Fair Isle were compared directly with the *Daily Weather Report*, which led to the conclusion that migration is stimulated by lack of wind, i.e. during anticyclonic conditions and in other conditions where pressure gradients over the area are slight. It is also probable that migration is stimulated by clear weather which allows of sun orientation.

Mr. Williamson showed a most comprehensive series of slides of various synoptic situations during 1951, and described the species of migrants recorded at Fair Isle on each occasion. These slides confirmed the ideas described, and strikingly showed that a drift-migrant's best way to ensure survival was to fly with the wind and cease attempts to fly in a "preferred direction". Thus, during outbreaks of arctic air masses, species from Iceland and even Spitsbergen arrive at Fair Isle; sometimes in autumn species from central Asia are found on the Frisian coasts and at Fair Isle when easterly currents from these regions persist for a few days. In the discussion which followed speakers stressed the interesting possibilities which were opened up as a result of the pioneer work of Mr. Williamson and the novel use of the *Daily Weather Report*. Cmdr. Frankcom referred to work of this nature carried out by ornithologists on British ocean weather ships, and Mr. Hay, in discussing the synoptic aspects of the paper, suggested that on occasions reports of rare migrants from such remote places could be a useful means of identifying air masses.

R. F. M. HAY

LETTER TO THE EDITOR

Remarkable changes in the screen temperature at Waddington

During the evening of December 5, and the morning of December 6, 1952, several abrupt changes of temperature were recorded in the screen at Waddington, the most remarkable occurring on the 6th when the temperature rose 13°F. in 2 hr. These changes are a good illustration of the temperature changes associated with valley stratification in light winds, and also afford a striking example of the effect of turbulence over the Lincoln Edge.

It is generally understood that when nocturnal cooling takes place on the slope of a hill or the side of a valley the cold air at the top of the slope drains into the valley below under the influence of gravity. Geiger has pointed out

that the cold air does not flow straight downhill as does water, but that little circulations are set up on the slope as warmer air flows in to the slope to take the place of that moving downhill. A cold "lake" is formed at the bottom of the slope, but as a result of the circulations a much warmer layer is found near the top of the slope. The resulting temperature distribution (according to Geiger) is shown in Fig. 1 together with a cross-section west to east through Waddington airfield. It will be seen from the cross-section that Waddington airfield (235 ft. above mean sea level) is near the crest of the Lincoln Edge, the eastern side of which slopes gently down to the Witham Valley, whilst to the west there is a sharp escarpment with a drop of about 200 ft. in 500 yd. The Lincoln Edge itself runs almost exactly north–south.

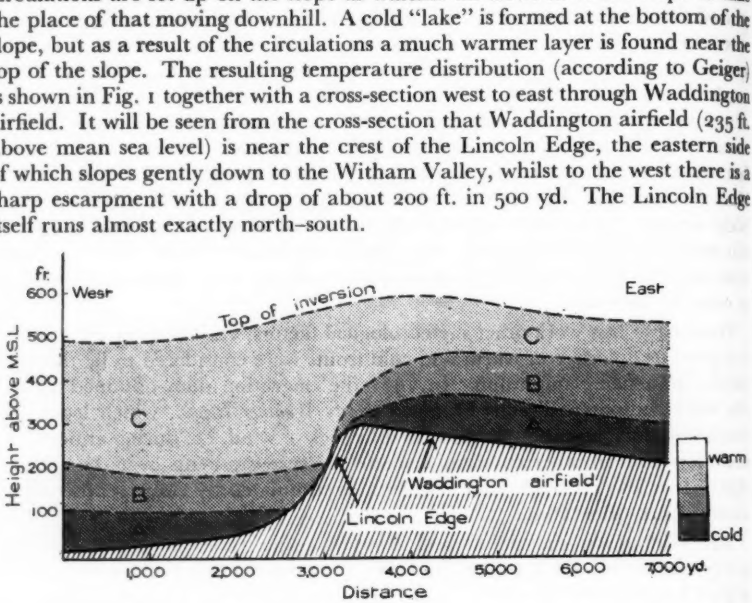


FIG. 1—TEMPERATURE DISTRIBUTION OVER LINCOLN EDGE, DECEMBER 5–6, 1952

The synoptic situation on the night of December 5–6, showed a ridge of high pressure from Poland extending westwards over the Low Countries and East Anglia with a light S.–SSW. gradient wind over Lincolnshire.

The Hemsby ascent was the most representative of air over Lincolnshire, and at 0200 on the 6th it showed a marked surface inversion with surface pressure and temperature, 1035 mb. and 30°F. respectively. The top of the inversion was at 1019 mb., where the temperature was 39°F. Allowing 28 ft./mb. the top of the inversion was 448 ft. above Hemsby and thus approximately 500 ft. above sea level.

The temperature at Waddington fell steadily during the late afternoon and early evening of the 5th. Applying the Hemsby ascent to Waddington it appears that a marked, but vertically very shallow, inversion developed at Waddington, and the top of this inversion may have been only 250–350 ft. above the airfield. Fig. 2 gives the temperature curve for Waddington from 1200 on the 5th to 2300 on the 6th, and hourly surface winds have been inserted. From Fig. 2 it can be seen that commencing at 1500 on the 5th temperature fell steadily, and by 1900 was down to 29·4°F., and that during this period the surface wind direction was 190° or further to the south-east. Between 1900 and 2000 the wind veered to 210° for a short period, and at 2000 the temperature had risen to 34·8°F., though by this time the wind had backed again to 170°. At 2100 the temperature had fallen again to 28·9°F. The wind veered to 210° at 2100 and continued at 200° or further west until 0600 on the 6th. The

temperature rose to 33·4°F. at 2200 and to 35·2°F. at 2300, but by 0600 had been reduced to 33·2°F. by slight nocturnal cooling. By 0700 the wind had backed again to 180° and the temperature had fallen to 28·5°F. The wind continued at 170–180° and by 0900 temperature had fallen to 26·2°F. Fog formed at 0745 when the temperature had fallen to 28·0°F.

During the next 2 hr. a remarkable rise of temperature occurred. The wind which had been from 170° at 0900 veered to 210° for a period around 1000. The temperature rose from 26·2°F. at 0900 to 29·0°F. at 1000, and by 1100 had reached 39·1°F. Thus a rise of 10°F. had occurred in 1 hr., but as the fog had cleared at 1030 it is possible that the change had occurred in less than 1 hr. and perhaps in as short a period as 40 min.

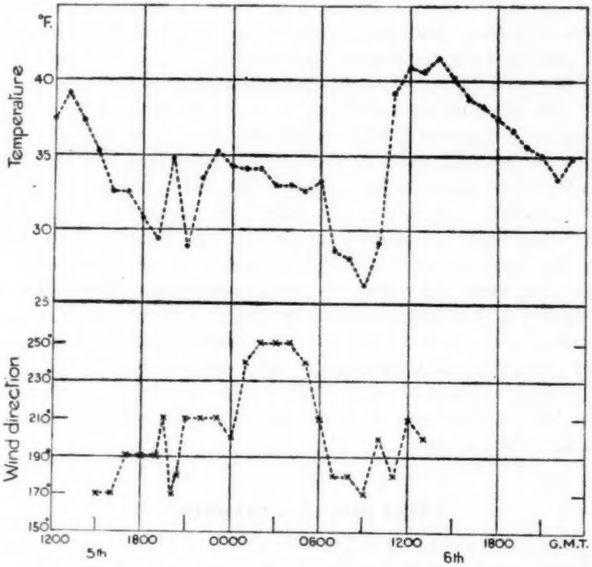


FIG. 2—HOURLY VALUES OF TEMPERATURE AND SURFACE WIND AT WADDINGTON, DECEMBER 5–6, 1952

The fluctuations of temperature were undoubtedly due to the onset and cessation of turbulence over the Lincoln Edge, the direction of the surface wind being the determining factor. As the wind veered to 200° or further to the west, turbulence occurred and warmer air (layer B or C, Fig. 1) was brought down and raised the screen temperature. As the wind backed from 200° cold air (layer A, Fig. 1) was brought back across the airfield again.

In the case of the 10°F. rise of temperature it is most probable that the turbulence associated with the veer of wind to 210° at 1000, together with the effect of the rising sun, was strong enough to break down the inversion completely, and in the resulting mixing the screen temperature was quickly raised to that of the air at the top of the inversion.

The turbulence on this occasion had an effect on the weather. Fog had been forecast to re-form early in the evening of the 5th; visibility however

remained at 2,500 yd. or more until 0745 on the 6th when the temperature fell and fog formed at the forecast fog point of 28°F. The fog cleared again during the period of the large temperature rise.

The orientation of the Lincoln Edge as stated earlier is 360–180° and the examples given above point to 200° as being a critical direction for turbulence over the Edge particularly in the vicinity of Waddington.

W. B. PAINTING

Waddington, December 27, 1952

NOTES AND NEWS

Exposure of instruments on an ocean weather ship

The photograph at the end of this issue of the O.W.S. *Weather Watcher* was taken by a *Scottish Daily Mail* photographer aboard an R.A.F. aircraft during a "Methop" (air-sea rescue) exercise on December 30, 1952. On this occasion the aircraft dropped New Year mail and newspapers to the ship in Lindholme containers, and some of the crew can be seen on the foredeck triumphantly holding their mails overhead. The figure in white is the ship's cook who performed a very important function on board on Christmas day and New Year's day. It will be seen from the photograph that the wind on the port beam is approximately force 4, and the ship although stopped is lying quietly and comfortably. The two temperature screens for wet- and dry-bulb readings can be very clearly seen on each side of the bridge, and on top of the balloon shelter aft can be seen the screen for the distant-reading thermograph which records humidity and temperature in the ship's meteorological office which is situated beneath the balloon shelter. The radar antenna on the platform between the bridge and the foremast is obviously following the aircraft as she encircles the ship. This is a radar which is used for upper wind observations. The smaller Decca radar used for navigational purposes will be noticed on the fore end of the wheel house.

C. E. N. FRANKCOM

Large pressure variations

Mr. M. H. O. Hoddinott, 19 Dickson Drive, Chester, writes that he and Mr. S. E. Ashmore propose to investigate the large pressure variations of July 6, 1952*, and asks for the loan of barograms for that day. Only clear barograms of which the error in time, if any, is known so that points in the trace can be timed to 5 minutes will be of use. Barograms lent will be returned as soon as a record has been made of the trace.

Mammatus cloud, Rickinghall, Suffolk, October 24, 1952

An unusually good display of mammatus and turbulence cloud occurred at Rickinghall, Suffolk (5 miles from Diss, Norfolk) at sunset on October 24, 1952. The photographs facing p. 192 were taken at 1640 and 1645 G.M.T. looking east to east-north-east at a receding line of cumulonimbus cloud. The sun had just set behind a neighbouring ridge and the low angle of illumination gave the cloud a brilliant orange hue against the background of greyish-purple cumulonimbus. Estimation of the height of the mammatus-cloud elements was difficult, but about 5,000 to 6,000 ft. was thought to be a near approximation.

* *Weather, London*, **7**, 1952, p. 291 and p. 320.

The following notes on the weather may be of interest. Rickinghall had had a moderate thunderstorm in the preceding 30 min. and hail up to 0·5 cm. diameter was lying 5–10 cm. deep in sheltered hollows. Examination of synoptic charts showed that at 1800 G.M.T. a deep depression centred at about 58°N. 15°W. was moving east slowly and was maintaining a south-westerly stream of unstable maritime polar air over England with general shower activity. Observations from neighbouring stations and "sferic" reports suggested that the storm and cloud formation was associated with a minor instability trough, although no marked squall was noticed.

Conditions representative of the air mass concerned are believed to be shown by the 1400 G.M.T. radio-sonde ascent from Hemsby. A fairly solid current of about 230–240°, 40–50 kt. existed up to 500 mb. Above that level there was very marked vertical shear associated with a jet stream with the wind reaching 250° 129 kt. at 300 mb. Temperature showed a dry adiabatic lapse rate up to the condensation level at about 850 mb. and a super wet adiabatic lapse rate 850 to 440 mb., apart from shallow stable layers at 775 to 750 mb. and 600 to 560 mb. Moisture content showed about 75 per cent. saturation below 700 mb. and somewhat drier conditions above. The freezing level was about 6,500 ft. These conditions would favour the development of marked instability phenomena up to about 500 mb. as was observed.

OBITUARY

Dr. James Esmond Belasco.—It is with great regret that we record the death on April 16, 1953, in his 59th year, of Dr. J. E. Belasco, Senior Scientific Officer, after a long service in the Meteorological Office dating back to January 1916.

Dr. Belasco had a wide experience, having served in the Marine Branch, the Instruments Branch, the Office in Edinburgh, in synoptic meteorology, and finally in the British Climatological Branch.

He wrote a number of important papers, amongst which may be mentioned:

The temperature characteristics of different classes of air over the British Isles in winter. *Quart. J.R. met. Soc., London,* **71,** 1945, p. 351.

Rainless days of London. *Quart J.R. met. Soc., London,* **74,** 1948, p. 339.

Characteristics of air masses over the British Isles. *Geophys. Mem., London,* **11,** No. 87, 1952.

Dr. Belasco set a fine example by his determination and courage to carry on although handicapped by heart trouble, which developed in later life, and which he expected would sooner or later overcome him. He leaves behind a widow to whom we offer our deepest sympathy.

Walter John Davies.—We regret to record the death of Mr. W. J. Davies, Experimental Officer, on March 22, 1953.

Mr. Davies joined the staff of the Office in February 1935, and served at Royal Air Force stations at home and overseas. His last six years of service were in Flying Training Command; in May 1946 he went to re-open and take charge of the meteorological office at Feltwell, and remained there until his sudden death. He developed an ideal technique in teaching elementary meteorology to new pupil pilots and had been complimented by the R.A.F. Central Examination Board and the Central Flying School Examiners.

Both Mr. Davies and his family took an active part in the social life at Feltwell. He was well liked and esteemed by his colleagues in the Office and in the R.A.F. Mr. Davies leaves a widow and a son and daughter to whom we offer our deepest sympathy in their loss.

ERRATUM

APRIL 1953, PAGE 105, TABLE I; All values of α in column 9 should be positive not negative.

BOOKS RECEIVED

8° Annuario 1951. Osservatorio di Fisica Terrestre del Seminario Arcivescovile di Milano. $13\frac{1}{2}$ in. $\times$ $9\frac{3}{4}$ in., pp. 36, *Illus.*, Societa' Arti Graphiche S. Abondio, Como, 1952.

Report on the administration of the Meteorological Department of the Government of India in 1950–51. $13\frac{1}{2}$ in. $\times$ $8\frac{1}{2}$ in., pp. ii + 46. India Meteorological Department, Delhi, 1952.

METEOROLOGICAL OFFICE NEWS

Sport and Athletics.—*Football.*—The Meteorological Office beat Finance by 3 goals to 1 in the final of the Air Ministry competition for the Football Cup at Northolt on May 5. Goals were scored by Martin, Mayes and Farr. This is the eleventh occasion on which the Meteorological Office have won the Cup and the sixth consecutive year. The win was somewhat unexpected since several of the previous year's team were unavailable owing to injury and new players had to fill their places.

Chess.—Mr. P. M. Shaw won the Air Ministry Chess Championship on behalf of the Meteorological Office.

Bishop Shield.—With points gained from swimming, cross country running, lawn tennis, football, chess and bridge, the Office are in a strong position to retain the Bishop Shield for the year which ends with the Air Ministry Sports on July 1, 1953.

WEATHER OF APRIL 1953

Mean pressure was below normal over most of North America and west Europe and above normal over the North Atlantic (north of latitude 45°N.) and east and south-east Europe. Mean pressure exceeded 1020 mb. over Greenland and was as much as 12 mb. above normal over the extreme south of this region; the mean pressure of 1015 mb. at the Azores, however, was 8 mb. below normal. Mean pressure was also low off the west coast of Norway where it fell to 1006 mb., about 6 mb. below normal.

Mean temperature was about 4°F. above normal over Europe and 4°F. below normal over the United States, except in the extreme east. In Europe the values of mean temperature were between 45° and 55°F.

In the British Isles the weather was sunny and rather cool; it was wet in most districts except south-west Scotland and Northern Ireland. A fine, sunny spell occurred from the 18th to the 25th apart from some rain in the north and west on the 23rd to 25th.

In the opening days pressure was low to the north of Scotland and associated troughs of low pressure moved north-east across the British Isles; cool weather

prevailed, with rain or showers, wintry in places. On the 4th a depression off west Ireland moved south-east and subsequently turned north-east across England and Wales to Denmark giving rain in most districts, except the north of Scotland, and local thunderstorms. On the 7th a wedge moved north-east across England and Wales, while a small secondary depression moved east over the north of Scotland; fair, sunny weather prevailed over England, Wales and most of Ireland but heavy showers fell at times in north-west Scotland. On the 8th a depression over the Bay of Biscay moved slowly north-east and a cold north to north-east stream of air spread over much of Scotland; rain occurred in the extreme south-west of England and in the Channel Islands and showers locally in Scotland. Early morning frost occurred rather widely in the west and north on the 7th, in the southern half of the country on the 8th and in northern districts on the 9th (temperature in the screen fell to 22°F. at Eskdalemuir on the 7th, 24°F. at Midleton, near Cork, on the 8th and 23°F. at Wick on the 9th). On the 10th a wedge moved south-east across the British Isles giving fair weather in England, Wales and the extreme south of Scotland. On the 11th a depression off the Hebrides moved north-east causing a severe gale and heavy rain locally in the north-west. Subsequently a cold front moved south-east across England giving a wet day in the south-east and east on the 12th. Thereafter pressure was high over the Atlantic and cold north-westerlies prevailed with some sleet or snow in Scotland. On the 15th a small depression moving south-east from north-east Scotland gave further snow in Scotland and this was followed by a deeper depression which gave rain in all areas. Subsequently a ridge of high pressure extended from the Atlantic across the British Isles to Germany and anticyclonic conditions persisted until the 23rd, with good records of bright sunshine from the 19th to the 23rd. The highest temperature of the month was registered at most places on one of the days from the 22nd to the 24th (70°F. at Valentia and 71°F. at Poole and Hurn on the 22nd). On the 24th and 25th rather cold northerly winds spread south, with snow showers in the north of Scotland but in most districts it remained fine over the 25th. On the 26th a depression moved south-east from westward of Ireland to the mouth of the English Channel, and during the following day it moved north-east to combine with another centre which moved north from the Strait of Dover; rain fell in all districts and was heavy locally. On the 29th another depression moved north-east across England to the North Sea giving general rain, heavy in some parts, particularly in Wales (2·51 in. at Llangurig, Montgomeryshire, 2·42 in. at Rhondda Water Works, Glamorganshire and 2·40 in. at Llyn-y-fan Fach, Carmarthenshire).

The general character of the weather is shown by the following provisional figures.

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	71	16	−1·4	138	0	114
Scotland	72	16	−1·8	118	+1	115
Northern Ireland ...	67	28	−2·2	84	−1	109

RAINFALL OF APRIL 1953

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	2·50	162	*Glam.*	Cardiff, Penylan	3·89	156
Kent	Dover	1·55	96	*Pemb.*	Tenby	2·32	101
,,	Edenbridge, Falconhurst	2·67	143	*Radnor*	Tyrmynydd	4·99	135
Sussex	Compton, Compton Ho.	2·41	121	*Mont.*	Lake Vyrnwy	5·00	158
,,	Worthing, Beach Ho. Pk.	2·53	162	*Mer.*	Blaenau Festiniog	7·07	114
Hants.	Ventnor Park	1·16	68	,,	Aberdovey	3·57	137
,,	Southampton (East Pk.)	1·80	97	*Carn.*	Llandudno	2·51	149
,,	S. Farnborough	2·06	135	*Angl.*	Llanerchymedd	3·28	148
Herts.	Royston, Therfield Rec.	1·92	122	*I. Man*	Douglas, Borough Cem.	3·33	136
Bucks.	Slough, Upton	2·30	161	*Wigtown*	Newton Stewart	1·82	71
Oxford	Oxford, Radcliffe	2·08	130	*Dumf.*	Dumfries, Crichton R.I.	2·67	113
N'hants.	Wellingboro' Swanspool	1·99	133	,,	Eskdalemuir Obsy.	4·40	129
Essex	Shoeburyness	1·61	133	*Roxb.*	Crailing	2·90	181
,,	Dovercourt	2·08	166	*Peebles*	Stobo Castle	2·93	140
Suffolk	Lowestoft Sec. School	1·74	117	*Berwick*	Marchmont House	2·82	140
,,	Bury St. Ed., Westley H.	2·50	163	*E. Loth.*	North Berwick Res.	1·94	139
Norfolk	Sandringham Ho. Gdns.	2·77	182	*Midl'n.*	Edinburgh, Blackf'd. H.	2·02	137
Wilts.	Aldbourne	2·64	143	*Lanark*	Hamilton W. W., T'nhill	1·76	94
Dorset	Creech Grange	2·56	119	*Ayr*	Colmonell, Knockdolian	1·58	62
,,	Beaminster, East St.	3·84	162	,,	Glen Afton, Ayr San.	3·78	126
Devon	Teignmouth, Den Gdns.	2·67	133	*Renfrew.*	Greenock, Prospect Hill	2·58	75
,,	Cullompton	3·10	137	*Bute*	Rothesay, Ardencraig	2·74	92
,,	Ilfracombe	2·45	117	*Argyll*	Morven (Drimnin)	3·87	106
,,	Okehampton	4·24	133	,,	Poltalloch	4·41	146
Cornwall	Bude, School House	2·34	124	,,	Inveraray Castle	4·75	103
,,	Penzance, Morrab Gdns.	2·72	112	,,	Islay, Eallabus	2·04	71
,,	St. Austell	3·04	108	,,	Tiree	2·84	115
,,	Scilly, Tresco Abbey	2·86	146	*Kinross*	Loch Leven Sluice	2·41	126
Glos.	Cirencester	2·69	144	*Fife*	Leuchars Airfield	2·47	155
Salop	Church Stretton	3·27	150	*Perth*	Loch Dhu	4·11	87
,,	Shrewsbury, Monkmore	2·80	189	,,	Crieff, Strathearn Hyd.	2·15	98
Worcs.	Malvern, Free Library	2·53	141	,,	Pitlochry, Fincastle	1·48	66
Warwick	Birmingham, Edgbaston	2·77	159	*Angus*	Montrose, Sunnyside	3·56	196
Leics.	Thornton Reservoir	2·37	139	*Aberd.*	Braemar	2·49	105
Lincs.	Boston, Skirbeck	2·13	158	,,	Dyce, Craibstone	2·52	122
,,	Skegness, Marine Gdns.	2·53	189	,,	New Deer School House	2·62	132
Notts.	Mansfield, Carr Bank	2·64	153	*Moray*	Gordon Castle	2·26	129
Derby	Buxton, Terrace Slopes	4·48	152	*Nairn*	Nairn, Achareidh	2·06	147
Ches.	Bidston Observatory	1·82	112	*Inverness*	Loch Ness, Garthbeg	4·02	123
,,	Manchester, Ringway	2·33	130	,,	Glenquoich	7·90	122
Lancs.	Stonyhurst College	3·40	125	,,	Fort William, Teviot	4·64	103
,,	Squires Gate	2·36	133	,,	Skye, Duntuilm	4·88	150
Yorks.	Wakefield, Clarence Pk.	1·97	117	,,	Skye, Broadford	5·97	132
,,	Hull, Pearson Park	2·12	136	*R. & C.*	Tain, Mayfield	1·82	99
,,	Felixkirk, Mt. St. John	2·51	150	,,	Inverbroom, Glackour	5·56	149
,,	York Museum	2·16	135	,,	Achnashellach	5·79	108
,,	Scarborough	2·43	156	*Suth.*	Lochinver, Bank Ho.	3·38	119
,,	Middlesbrough	1·40	102	*Caith.*	Wick Airfield	2·14	108
,,	Baldersdale, Hury Res.	3·08	141	*Shetland*	Lerwick Observatory	2·89	126
Norl'd.	Newcastle, Leazes Pk.	2·45	154	*Ferm.*	Crom Castle	1·25	49
,,	Bellingham, High Green	3·76	174	*Armagh*	Armagh Observatory	2·17	103
,,	Lilburn Tower Gdns.	3·05	154	*Down*	Seaforde	2·08	79
Cumb.	Geltsdale	2·97	139	*Antrim*	Aldergrove Airfield	1·05	50
,,	Keswick, High Hill	3·82	124	,,	Ballymena, Harryville	2·32	88
,,	Ravenglass, The Grove	2·52	102	*L'derry*	Garvagh, Moneydig	2·30	94
Mon.	Abergavenny, Larchfield	3·79	150	,,	Londonderry, Creggan	3·10	121
Glam.	Ystalyfera, Wern House	5·33	140	*Tyrone*	Omagh, Edenfel	2·35	89

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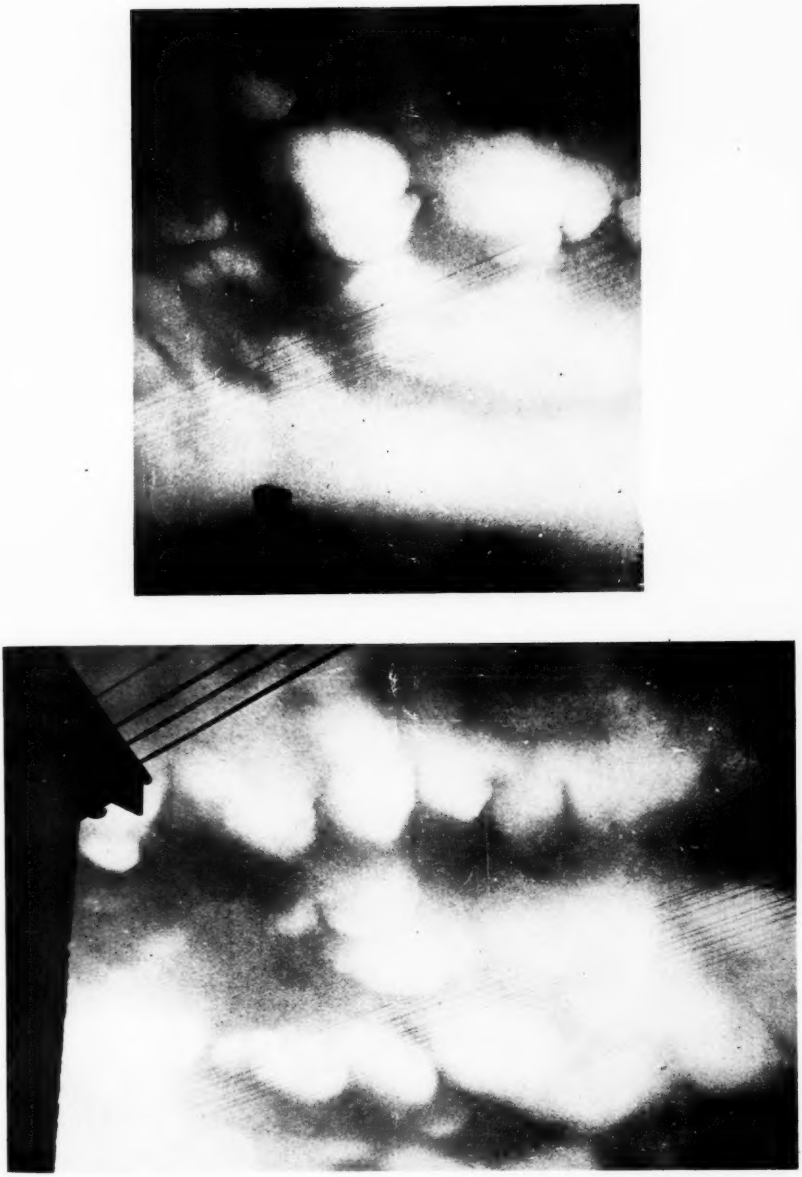

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MAMMATUS CLOUD, RICKINGHALL, SUFFOLK, OCTOBER 24, 1952

(see p. 188)

Reproduced by courtesy of the Scottish Daily Mail

O.W.S. WEATHER WATCHER. 'TATION I, DECEMBER 30, 1952

(see ·88)

O.W.S. WEATHER WATCHER. 'TATION I, DECEMBER 30, 1952
(see ·88)

To face p. 193]

E. G. BILHAM, B.Sc., D.I.C.